1

UNDERSTANDING THE STARRY SKY

And that inverted bowl we call the Sky
Where under crawling coop't we live and die
Lift not your hands to it for help—for It
As impotently rolls as you and I.

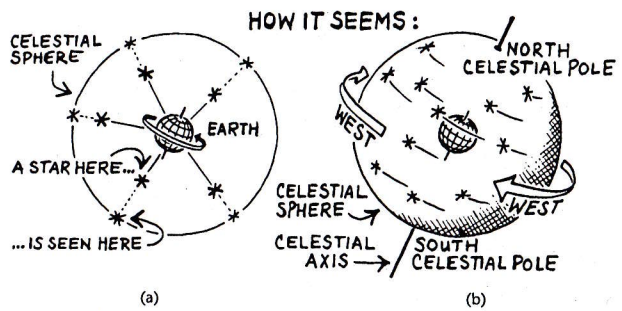
Rubáiyát of Omar Khayyám (1048–1131)

Objectives

- ☆ Locate sky objects by their right ascension and declination on the celestial sphere.
- ☆ Identify some bright stars and constellations visible each season.
- ☆ Explain why the stars appear to move along arcs in the sky during the night.
- ☆ Explain why some different constellations appear in the sky each season.
- ☆ Explain the apparent daily and annual motions of the Sun.
- ☆ Define the zodiac.
- ☆ Describe how the starry sky looks when viewed from different latitudes on Earth.
- ☆
- ☆ Explain how astronomers classify objects according to their apparent brightness (magnitude).
- ☆ Explain why the polestar and the location of the vernal equinox change over a period of thousands of years.

1.1 STARGAZER'S VIEW

On a clear, dark night the sky looks like a gigantic dome studded with stars. We can easily see why the ancients believed that the starry sky was a huge sphere turning around Earth.



(a) (b)

Figure 1.1. (a) To a stargazer on Earth, all stars appear equally remote. (b) We picture the stars as fixed on a celestial sphere that spins westward daily (opposite to Earth's actual rotation).

Today we know that stars are remote, blazing Suns racing through space at different distances from Earth. The Earth **rotates**, or turns, daily around its **axis** (the imaginary line running through its center between the North and South Poles).

But the picture of the sky as a huge, hollow globe of stars that turns around Earth is still useful. Astronomers call this fictitious picture of the sky the **celestial sphere**. "Celestial" comes from the Latin word for heaven.

Astronomers use the celestial sphere to locate stars and galaxies and to plot the courses of the Sun, Moon, and planets throughout the year. When you look at the stars, imagine yourself inside the celestial sphere looking out (Figure 1.1).

Why do the stars on the celestial sphere appear to move during the night when you observe them from Earth? _____

Answer: Because the Earth is rotating on its axis inside the celestial sphere.

1.2 CONSTELLATIONS

It is fun to go outside and see a young blue-white star or a dying red giant star in the sky right after you read about them. You may think you will never be able to tell one star from another when you begin stargazing, but you will.

The removable star maps at the back of this book have been drawn especially for beginning stargazers observing from around 40°N latitude. (They

should be useful to new stargazers throughout the midlatitudes of the northern hemisphere.)

Stars appear to belong to groups that form recognizable patterns in the sky. These star patterns are called **constellations**. Learning to identify the most prominent constellations will help you pick out individual stars.

The 88 constellations officially recognized by the International Astronomical Union are listed in Appendix 1. Famous ones that shine in these latitudes are shown on your star maps. Their Latin names, and the names of **asterisms**, or popular unofficial star patterns, are printed in capital letters.

Thousands of years ago people named the constellations after animals, such as Leo the Lion (Figure 1.2), or mythological characters, such as Orion the Hunter (Figure 5.1). More than 2000 years ago the ancient Greeks recognized 48 constellations.

Modern astronomers use the historical names of the constellations to refer to 88 sections of the sky rather than to the mythical figures of long ago. They refer to constellations in order to locate sky objects. For instance, saying that Mars is in Leo helps locate that planet, just as saying that Houston is in Texas helps locate that city.

Look over your star maps. Notice that the dashed line indicates the **ecliptic**, the apparent path of the Sun against the background stars. The 12 constellations located around the ecliptic are the constellations of the zodiac whose names are familiar to horoscope readers.

List the 12 constellations of the zodiac_____

Answer: Pisces, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius.

(a) (b)

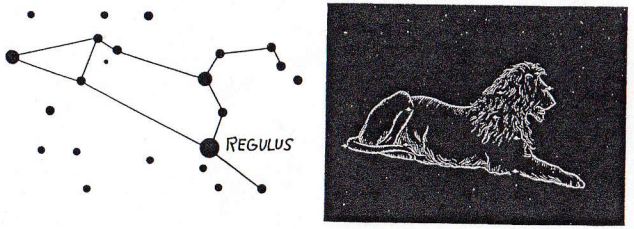


Figure 1.2. Constellation Leo is best seen in early spring when it is high in the sky. (a) Brightest star Regulus marks the lion's heart, a sickle of stars his mane, and a triangle of stars his hindquarters and tail. (b) Leo the Lion.

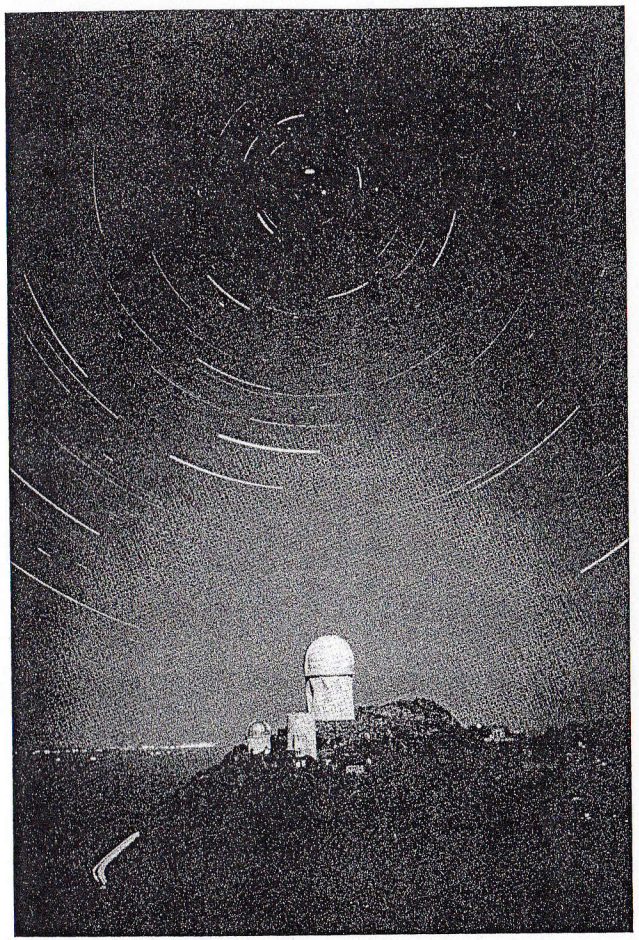


Figure 1.3. A time exposure taken with a camera aimed at the north celestial pole over the U.S. Kitt Peak National Observatory shows star trails that mirror Earth's actual rotation.

1.3 CIRCUMPOLAR CONSTELLATIONS

Study your star maps carefully. You will notice that several **circumpolar constellations**, near the north celestial pole (marked POLE +), appear on all four maps.

These are **north circumpolar constellations**, visible above the northern horizon all year long at around 40°N latitude (Figure 1.3). At this latitude, the south celestial pole and nearby **south circumpolar constellations** do not rise above the horizon any night of the year.

List the three circumpolar constellations closest to Polaris (the North Star) and sketch their outlines. _____

Answer: Three circumpolar constellations that you should be able to pick out on the star maps are Cassiopeia, Cepheus, and Ursa Minor. After you know their outlines, try to find them in the sky above the northern horizon. *Note:* At latitude 40°N or higher, Ursa Major and Draco are also circumpolar.

1.4 HOW TO USE THE STAR MAPS

Use our Star Chart!

You can use the star maps outdoors to *identify* the constellations and stars you see in the night sky and to *locate* those you want to observe.

Choose the map that pictures the sky at the month and time you are stargazing. Turn the map so that the name of the compass direction you are facing appears across the bottom. Then, from bottom to center, your star map pictures the sky as you are viewing it from your horizon to the point directly over your head.

For example, if you are facing north about 10:00 P.M. in early April, turn the map so that the word NORTH is at the bottom. From the horizon up, you may observe Cassiopeia, Cepheus, the Little Dipper in Ursa Minor, and the Big Dipper in Ursa Major.

Name a prominent constellation that shines in the south at about 8:00 P.M. in early February. _____

Answer: Orion.

1.5 HOW TO IDENTIFY CONSTELLATIONS

The constellations above the southern horizon parade by during the night and change with the seasons. Turn each map so that the word SOUTH is at the bottom. Use your star maps to identify the most prominent constellations that shine each season (such as Leo in the spring and Orion in the winter).

Identify and sketch three constellations that you can see this season.

_____

_____

Answer: Your answer will depend on the season. For example, if you are reading this book in the spring, you might choose Leo, Virgo, and Boötes.

1.6 STAR NAMES

Long ago, more than 50 of the brightest stars were given proper names in Arabic, Greek, and Latin. The names of bright or famous stars to look for are printed on your star maps with the initial letters capitalized.

Today astronomers use alphabets and numerals to identify hundreds of thousands of stars. They refer to each of the brightest stars in a constellation by a Greek letter plus the Latin genitive (possessive) form of the constellation name. Usually the brightest star in a constellation is α, the next brightest is β, and so on. (The Greek alphabet is listed in Appendix 3.) Thus, Regulus is called α Leonis, or the brightest star of Leo. Fainter stars, not shown on your maps, are identified by numbers in star catalogs.

In a built-up metropolitan area you can see only the brightest stars. When you are far from city lights and buildings and the sky is very dark and clear, you can see about 2000 stars with your unaided eye.

Name the three bright stars that mark the points of the famous Summer Triangle. Refer to your summer skies map. _____

_____

Answer: Vega, Deneb, and Altair. Look for the Summer Triangle overhead during the summer.

1.7 BRIGHTNESS

Some stars in the sky look brighter than others. The **apparent magnitude** of a sky object is a measure of its observed brightness as seen from Earth. Stars

may look bright because they send out a lot of light or because they are relatively close to Earth.

In the second century B.C., the Greek astronomer Hipparchus divided the visible stars into six classes, or magnitudes, by their relative brightness. He numbered the magnitudes from 1 (the brightest) through 6 (the least bright).

Modern astronomers use a more precise version of the ancient classifying system. Instead of judging brightness by the eye, they use an instrument called a **photometer** to measure brightness. Magnitudes for the brightest stars are negative—the brightest night star, Sirius, measures −1.46. Magnitudes range from −26.72 for the Sun to about +28 for the faintest objects observed in large telescopes. A difference of 1 magnitude means a brightness ratio of about 2.5.

Magnitudes are shown on your star maps and in Table 1.1. For example, we receive about 2.5 times as much light from Vega, a star of magnitude 0, as we do from Deneb, a star of magnitude 1, and about 6.3 times as much light as from Polaris, of magnitude 2. (Magnitudes are discussed further in Section 3.14.)

What do astronomers mean by "apparent magnitude"? _____

_____

Answer: How bright a sky object looks.

1.8 LOCATION ON EARTH

The more you understand about stars and their motions, the more you will enjoy stargazing. A **celestial globe** helps you locate sky objects as a **terrestrial** (Earth) **globe** helps you locate places on Earth.

Remember how Earth maps work. We picture the Earth as a sphere and draw imaginary guidelines on it. All distances and locations are measured from two main reference lines, each marked 0°. One line, the **equator**, is the great circle halfway between the North and South Poles that divides the globe into halves. The other line, the **prime meridian**, runs from pole to pole through Greenwich, England.

Imaginary lines parallel to the equator are called **latitude** lines. Those from pole to pole are called **longitude** lines, or **meridians**. You can locate any city on Earth if you know its coordinates of latitude and longitude. Distance on the terrestrial sphere can be measured by dividing the sphere into 360 sections, called **degrees** (°). (Angular measure is defined in Appendix 3.)

Refer to the globe in Figure 1.4. Identify the equator; prime meridian; 30°N latitude line; and 30°E longitude line. (a) _____ ; (b) _____ ; (c) _____ ; (d) _____

Answer: (a) 30°N; (b) 30°E; (c) equator; (d) prime meridian.

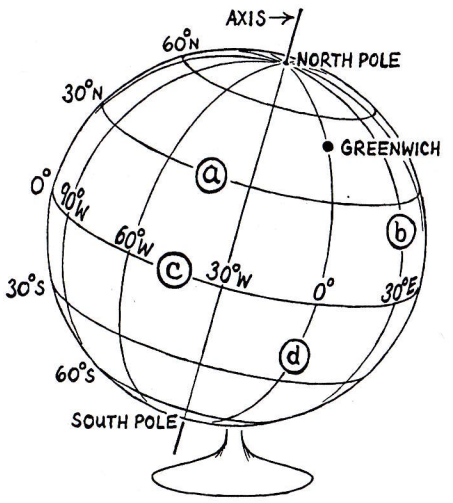


Figure 1.4. Terrestrial globe.

1.9 CELESTIAL COORDINATES

Astronomers draw imaginary horizontal and vertical lines on the celestial sphere similar to the latitude and longitude lines on Earth. They use celestial coordinates to specify directions to sky objects.

The **celestial equator** is the projection of the Earth's equator out to the sky. Angular distance above or below the celestial equator is called **declination (dec)**. Distance measured eastward along the celestial equator from the zero point, the **vernal equinox**, is called **right ascension (RA)**. Right ascension is commonly measured in hours (h), with $1^h = 15°$.

Just as any city on Earth can be located by its coordinates of longitude and latitude, any sky object can be located on the celestial sphere by its coordinates of right ascension and declination.

Give the location of the star shown in Figure 1.5. _____

Answer: 20^h RA, 30°N declination.

_____

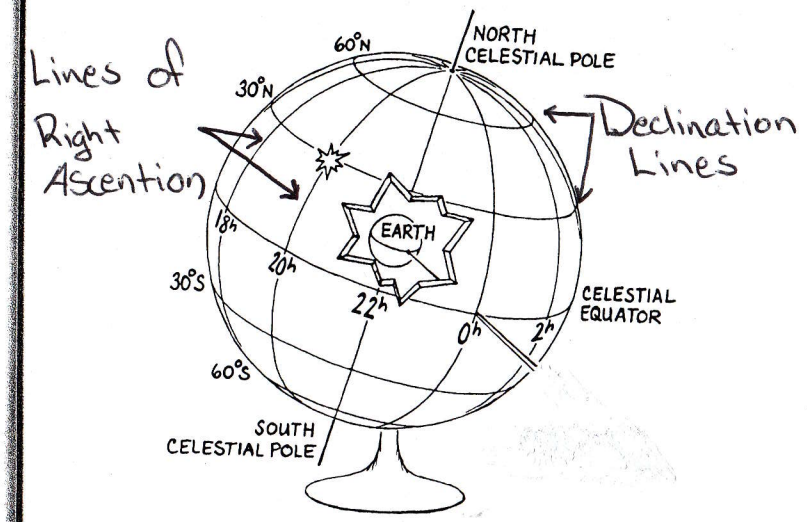


Figure 1.5. Celestial globe.

1.10 LOCATION ON THE CELESTIAL SPHERE

Every star has a location on the celestial sphere, where it appears to be when sighted from Earth. The right ascension and declination of stars for a standard **epoch**, or point of time selected as a fixed reference, change little over a period of many years. They can be read from a celestial globe, star atlas, or computer software. (See Table 1.1, for example. You'll be referring to this table when the information it contains is discussed in later chapters.)

The locations of the Sun, Moon, and planets on the celestial sphere change regularly. You can find their monthly positions in current astronomical publications, Web sites, and computer software (see "Useful Resources").

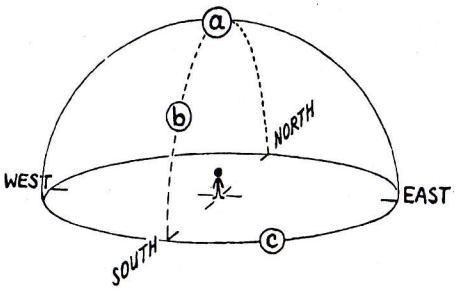


Figure 1.6. A stargazer's local reference lines.

1.11 LOCAL REFERENCE LINES

Lines of declination and right ascension are fixed in relation to the celestial sphere and move with it as it rotates around an observer. Other useful reference lines relate to the local position of each observer and stay fixed with the observer while sky objects pass by.

At your site, the **zenith** is the point on the celestial sphere directly over your head. The **celestial horizon** is the great circle on the celestial sphere 90° from your zenith. Although the celestial sphere is filled with stars, you can see only those that are above your horizon. The **celestial meridian** is the great circle passing through your zenith and the north and south points on your horizon. Only half of the celestial meridian is above the horizon.

Refer to Figure 1.6. Identify the stargazer's zenith; celestial horizon; and celestial meridian. (a) _____; (b) _____; (c) _____

Answer: (a) Zenith; (b) meridian; (c) horizon.

1.12 CELESTIAL MERIDIAN

Go outside and trace out your zenith, celestial horizon, and celestial meridian by imagining yourself, like that stargazer, at the center of the huge celestial sphere.

If possible, try this on a clear, dark, starry night. Face south. Observe the stars near your celestial meridian several times during the night. Describe what you observe. _____

_____

_____

Answer: The stars move from east to west and **transit**, or cross, your celestial meridian. This is because of the Earth's rotation from west to east. A star **culminates**, or reaches its highest altitude, when it is on the celestial meridian.

1.13 LATITUDE AND STARGAZING

The stars that appear above your horizon and their paths across the sky depend on your latitude on Earth. The sky looks different from different latitudes (Figure 1.7).

If you could look at the sky from the North Pole and then from the South Pole you would see completely different stars. The Earth cuts your view of the celestial sphere in half.

You can determine how the celestial sphere is oriented with respect to your horizon and zenith at any place on Earth. In the northern hemisphere, the north celestial pole is located above your northern horizon at an altitude equal to your latitude. Polaris, the polestar, or North Star, is less than one degree away from the north celestial pole and marks the position of the pole in the sky. The declination circle that is numerically equal to your latitude passes through your zenith. In the southern hemisphere, the south celestial pole is located above your southern horizon at an altitude equal to your latitude. It is not marked by a polestar.

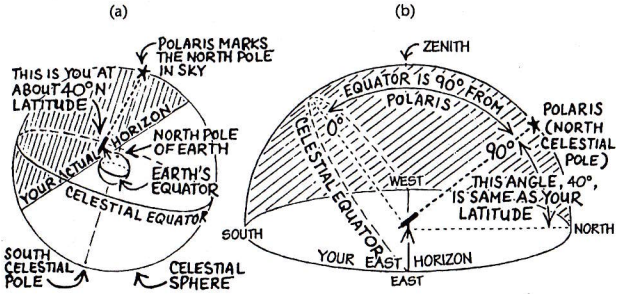


Figure 1.7. Local orientation of the celestial sphere at 40°N latitude. (a) View from a fictitious spot on the outside. (b) Stargazer's view.

Where would you look for the North Star if you were at each of the following locations: (a) the North Pole? _____ (b) the equator? _____ (c) 40°N latitude? _____ (d) your home? _____

Answer: (a) At your zenith; (b) on your horizon; (c) 40° above your northern horizon; (d) at an altitude above your northern horizon equal to your home latitude.

1.14 APPARENT DAILY MOTION OF THE STARS

The stars appear to move in **diurnal circles,** or daily paths, around the celestial poles when you observe them from the spinning Earth.

Although the North Star, Polaris, is not a very bright star, it has long been important for navigation. Closest to the north celestial pole, it is the only star that seems to stay in the same spot in the sky. You can find Polaris by following the "pointer stars," Dubhe and Merak, in the bowl of the Big Dipper in the constellation Ursa Major. (Figure 1.8).

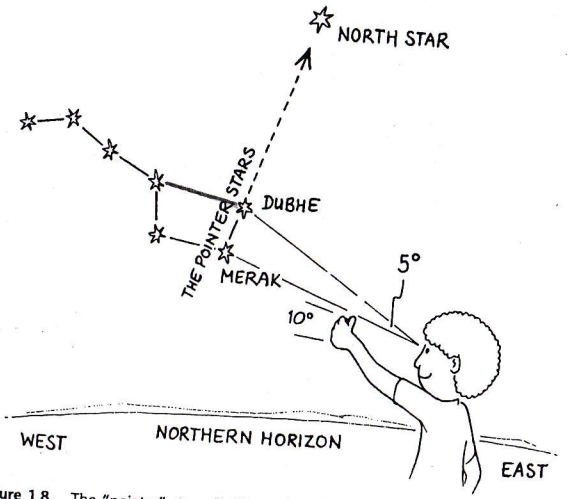


Figure 1.8. The "pointer" stars, Dubhe and Merak, in the bowl of the Big Dipper lead you to the North Star, Polaris. The angular distance between these pointer stars is about 5° on the celestial sphere. A fist at arm's length marks about 10°. These examples will help you judge other angular distances in the sky.

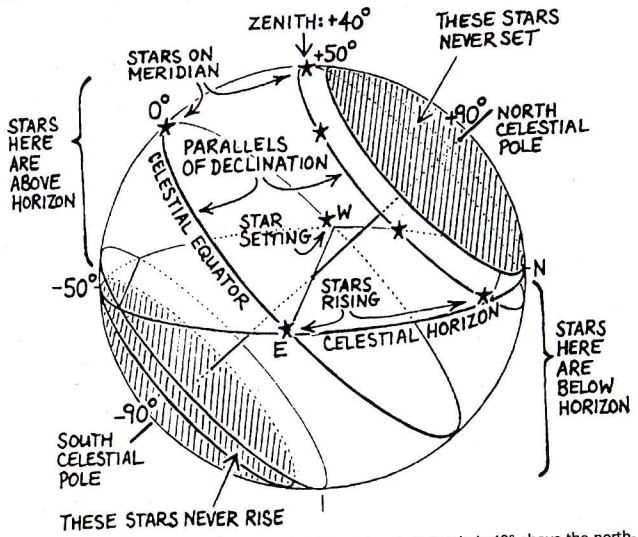


Figure 1.9. The sky from 40°N latitude. The north celestial pole is 40° above the northern horizon, and the celestial sphere rotates around it. Parallels of declination mark the stars' diurnal circles.

Since the celestial poles are at distinct altitudes in the sky at distinct latitudes, the part of a star's diurnal circle that is above the horizon is different at different latitudes on Earth. (Figure 1.9).

For example, if you stargaze at 40°N latitude, about the latitude of Denver, Colorado, U.S., you will see (Figure 1.9): (1)Stars within 40° (your latitude) of the north celestial pole (those stars between +50° and +90° declination) are always above your horizon. These stars that never set—such as the stars in the Big Dipper—are **north circumpolar stars.** (2) Stars that are within 40° (your latitude) of the south celestial pole never appear above your horizon. These stars that never rise—such as the stars in the constellation Crux, the Southern Cross—are **south circumpolar** stars. (3) The other stars, in a band around the celestial equator, rise and set. Those stars that are located at 40°N declination (equal to your latitude) pass directly across your zenith when they cross your celestial meridian.

Q-Town = 41° N

1.15 UNUSUAL VIEWS

Describe how the diurnal circles of the stars would look if you were stargazing at (a) the North Pole and (b) the equator. Explain your answer. *Tip:* Remember that the celestial sphere rotates around the celestial poles. (a) _____

(b) _____

Answer: (a) All stars would seem to move along circles around the sky parallel to your horizon. The celestial sphere rotates around the north celestial pole, which is located at your zenith at the North Pole. (b) All stars would seem to rise at right angles to the horizon in the east and set at right angles to the horizon in the west. The celestial sphere rotates around the celestial poles, which are located on your horizon at the equator.